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REVERBERATION MODELING FOR THE AN/SQS-26 SONAR SYSTEM.(U)
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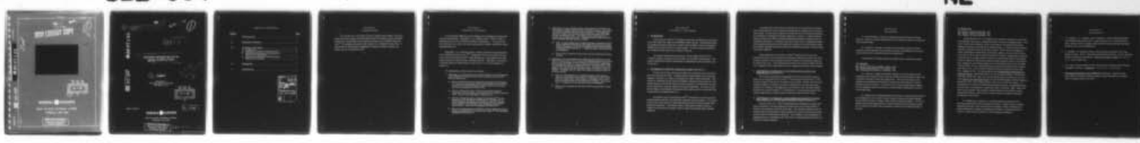

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SECTION I
INTRODUCTION

For the past year, the General Electric Company Heavy Military Electronic Systems has had a contract with Naval Ship Systems Command to obtain a statistical model of the reverberation at the beamformer output of the AN/SQS-26 Sonar System.[1] The program presented in this proposal is a continuation of that work. A theoretical and experimental investigation is proposed to extend, simplify, and further test the reverberation model.

SECTION II
PROPOSED PROGRAM

To accommodate different levels of funding, the investigation is broken down into three subprograms. Subprogram 1 is a minimum effort. Either or both of Subprograms 2 and 3 can be funded in addition to Subprogram 1. A one-year contract is proposed, no matter how many subprograms are funded, starting not sooner than September 1970.

Subprogram 1 is a theoretical effort to obtain extensions and simplifications of the existing theoretical model.[1,2] Subprograms 2 and 3 are repeats of the previous contract experimental work[1] using different data. Subprogram 2 uses data already available at Heavy Military Electronic Systems. Subprogram 3 uses data to be obtained during the Mediterranean cruise of the U.S.S. Glover scheduled for August 1970.

The subprograms and their tasks are as follows:

1) Subprogram 1 is theoretical work to obtain extensions and simplifications of the existing[1,2] theoretical model for the special case of the AN/SQS-26 sonar system.

   a) Task 1 is theoretical work to determine the probability distribution of a mixture of Gaussian and Poisson distributions in the reverberation and to develop test statistics to test the data for this mixture. (See the first paragraph of Section III.B.)

   b) Task 2 is theoretical work to relate the observable statistical properties of the sea surface to the statistics of the surface reverberation. (See the second paragraph of Section III.B.)

   c) Task 3 is theoretical work to simplify the expressions[3] for the covariance of the AN/SQS-26 reverberation. The objective is to obtain simplified expressions which need a minimum of computer time to evaluate, and which give more insight into the nature of reverberation. (See the third paragraph of Section III.B.)

   d) Task 4 is the performance of theoretical work to explain the discrepancies previously noted in the surface duct model.[1] (See the fourth paragraph of Section III.B.)

2) Subprogram 2 is the estimation of the reverberation time statistics for data already existing at Heavy Military Electronic Systems, and comparison of these estimates with theoretical predictions. This subprogram would be a repeat of the previous contract effort with fewer data tapes, but with no theoretical work. The purpose of this subprobram is to further test the theoretical model. Advantage would be taken of the software developed under the previous contract.

   a) Task 1 is experimental work to obtain estimates of statistical parameters predicted by the model for the surface duct and bottom bounce modes of operation, and to test the hypothesis that the reverberation is Gaussian (see Section III. C). A minimum of four data tapes would be investigated.

   b) Task 2 is the comparison of the theory with the experimental results of Task 1.

3) Subprogram 3 is the estimation of reverberation time statistics for new data to be taken on the U. S. S. Glover in the Mediterranean in the summer of 1970, and comparison of these estimates with theoretical predictions. This subprogram would be a repeat of the previous contract effort using this new data, but without the theoretical work. The purpose of this subprogram is to further test the theoretical model with data from this new location. Advantage would be taken of the software developed under the previous contract.

   a) Task 1 is experimental work to obtain estimates of the statistical parameters predicted by the model for the particular mode of operation (e.g. surface duct, bottom bounce, convergence zone), and to test the hypothesis that the reverberation is Gaussian. (See Section III. D.) A maximum of six data tapes would be investigated.

   b) Task 2 is the comparison of the theory with the experimental results of Task 1.

SECTION III
TECHNICAL DISCUSSION

A. BACKGROUND

In the previous contract,[1] statistical models were obtained for the reverberation at the beamformer output of the AN/SQS-26 Sonar System. Reverberation statistics predicted by these models were compared with estimates of the same statistics obtained from sea data in order to test the models. All three modes of operation of the AN/SQS-26 Sonar System were modeled in this way.

The results obtained from the previous contract suggest follow-on work to extend, simplify, and further test the model, as described in this proposal. This section contains brief technical discussions to supplement the task statements given in Section II.

B. EXTENSIONS OF PREVIOUS THEORETICAL WORK (Subprogram 1)

Work on the previous contract has pointed up some features of the data which need to be explored more fully. It appears that the reverberation is not everywhere Gaussian, but rather is a mixture of Gaussian and "spiky" Poisson processes. This mixture is consistent with the model and probably results from the presence of a few large scatterers mixed in with numerous small scatterers; or perhaps there are just too few scatterers to make the central limit theorem applicable. As an aid to sonar system design, the probability distribution of this mixture should be determined, and a means found of testing the data for it.

An extension of the reverberation model[2] is necessary to relate the reverberation statistics directly to the observable statistics of the sea surface. The current version of the model assumes Poisson-distributed scatterers without actually identifying these scatterers. A theoretical study to relate these scatterers and their motion to the observable sea surface would be useful in predicting sonar operating conditions.

A simplification of the theoretical equations for the reverberation covariance would considerably aid in their application and give greater insight into the reverberation process. On the previous contract the predictions of the reverberation statistics were obtained by evaluating complicated integrals by computer. An effort should be made to eliminate this effort by making simplifying assumptions compatible with the AN/SQS-26 parameters. In addition to the labor saving, such a simplification should yield equations which provide more insight into the nature of the reverberation statistics and their dependence upon system and environmental parameters, without solving complicated equations.

Results obtained on the previous contract[1] indicate that the model can successfully predict volume and bottom reverberation statistics, but that some modification is needed for the successful prediction of surface reverberation statistics in the surface duct mode. This modification would add to the model the effects believed to be responsible for the discrepancy (surface roughness and platform depth changes).

C. EXPERIMENTAL ESTIMATION OF REVERBERATION STATISTICS FOR EXISTING DATA (Subprogram 2)

The precise experimental measurements which are made and the means by which they are compared with the model[1,2] were described in Section III.C of the previous proposal[4] and will not be repeated here in detail. Briefly, these were the testing for ensemble, testing for normality, estimation of mean and mean square, estimation of covariance, and estimation of the spectrum of the covariance (instantaneous power spectral density).[3] In Subprogram 1 of the proposed program these measurements would be repeated again on new data to further test the model.

D. EXPERIMENTAL ESTIMATION OF REVERBERATION STATISTICS FOR NEW DATA FROM U.S.S. GLOVER MEDITERRANEAN TESTS (Subprogram 3)

Data from the U.S.S. Glover Mediterranean tests scheduled for August 1970 would be subjected to the same analysis as performed on the previous contract to determine the statistical properties of this data. The measured statistics would be compared with the theoretically predicted statistics to see if the model would predict reverberation for Mediterranean conditions. The completion of this subprogram is contingent upon the compatibility of the data with our existing equipment and the suitability of the data for analysis.

SECTION IV
PERSONNEL

Dr. David Middleton, acting as a consultant to Heavy Military Electronic Systems, would have primary responsibility for the theoretical work to be performed on the proposed tasks.

Dr. Thomas G. Kincaid, an employee of the General Electric Corporate Research and Development Center would have primary responsibility for the experimental work and the comparison of theory and experiment.

Heavy Military Electronic Systems personnel would be available as needed.

T.G. KINCAID

BSc, Queen's University, Kingston, Ontario, 1959
SM, Massachusetts Institute of Technology, 1961
PhD, Massachusetts Institute of Technology, 1965

Dr. Kincaid is a signals and systems engineer in the Information Sciences Laboratory of the General Electric Corporate Research and Development Center, and is presently working on active and passive sonar. His work in the passive area emphasizes the detection and estimation of waveforms and the effects of medium distortion of these waveforms. In the active area he has designed optimum signals for echo ranging in random media and is currently fitting a mathematical model to reverberation data.

Dr. Kincaid was a teaching assistant and instructor at Massachusetts Institute of Technology from 1959 to 1965, when he became an electronic systems engineer with the General Electric Company, Heavy Military Electronic Systems. In 1970, he assumed his present position with the Corporate Research and Development Center. He is a member of the IEEE and an associate member of the Acoustical Society of America.

D. MIDDLETON

AB, Physics, Harvard University, 1942
AM, Physics, Harvard University, 1945
PhD, Phisics, Harvard University, 1947

During World War II, Dr. Middleton was a Research Associate at the Harvard Radio Research Laboratory, working in the field of electronic countermeasures. From 1947 to 1949 he was a Research Fellow in electronics at the Harvard Electronics Research Laboratory of the Division of Applied Science. In 1949 he became Assistant Professor of Applied Physics in the same division. Since 1954 he was engaged in private consulting and research with universities, industry, and the armed services. From 1960 to 1961 he was an Adjunct Professor of Electrical Engineering at Columbia University and is currently Adjunct Professor of Applied Physics and Communication Theory at Rensselaer Polytechnic Institute (Hartford Graduate Center), East Windsor Hill, Connecticut, and Adjunct Professor of Communication Theory at the University of Rhode Island. He was a national Research Council Predoctoral Fellow in physics from 1946 to 1947, and received the National Electronics Conference Award (with W.H. Huggins) in 1956. His publications include An Introduction to Statistical Communication Theory, International Series in Pure and Applied Physics, McGraw-Hill, New York, March 1960, with a two-volume Russian edition, Soviet Radio, 1961 and 1962; Topics in Communication Theory, McGraw-Hill Monographs in Modern Engineering Science, 1965, with a Russian edition, 1966; and over sixty-five papers. His principal field of research is statistical communication theory, including applications in electronics, electron physics, underwater sound, seismology, radar, optics, and space communications, with emphasis on signal detection and extraction, system design and evaluation, and the study of various problems in applied mathematics appropriate to these fields.

Dr. Middleton is a Fellow of the American Physical Society and of the American Association for the Advancement of Science, a member of the American Mathematical Society, New York Academy of Sciences, Society of Industrial and Applied Mathematics, Institute of Mathematical Statistics, Acoustical Society of America, Optical Society of America, Phi Beta Kappa, and Sigma Xi.

SECTION V
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3. W.D. Mark, "Special Analysis of the Convolution and Filtering of Non-Stationary Stochastic Processes," J. Sound Vib., Vol. 11, No. 1, 19-63, (1970).

4. Reverberation Modeling for the AN/SQS-26 Sonar System, General Electric Heavy Military Electronic Systems proposal to Naval Ship Systems Command, Sonar Technology Branch, July 1968.